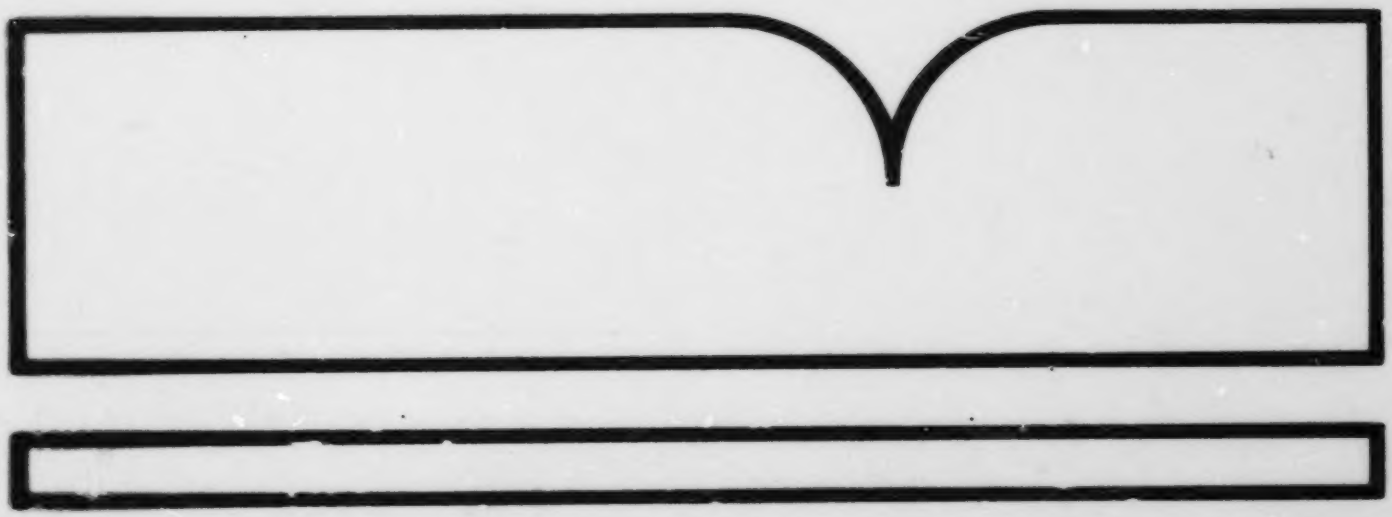
PB90-262916

Pilot Evaluation of Enhanced E-SOx Process

Acurex Corp., Research Triangle Park, NC

Prepared for:
Environmental Protection Agency, Research Triangle Park, NC

1990



U.S. Department of Commerce
National Technical Information Service
NTIS

AEERL-P-692

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before complet

1. REPORT NO. EPA/600/D-90/096	2.	3. PB90-262916
4. TITLE AND SUBTITLE Pilot Evaluation of Enhanced E-SOx Process		5. REPORT DATE
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) J. C. S. Chang (Acurex) and L. S. Hovis (EPA/AEERL)		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Acurex Corporation P. O. Box 13109 Research Triangle Park, North Carolina 27709		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. 68-02-4701
12. SPONSORING AGENCY NAME AND ADDRESS EPA, Office of Research and Development Air and Energy Engineering Research Laboratory Research Triangle Park, North Carolina 27711		13. TYPE OF REPORT AND PERIOD COVERED Published paper; 5/89-2/90
		14. SPONSORING AGENCY CODE EPA/600/13

15. SUPPLEMENTARY NOTES AEERL project officer is Louis S. Hovis, Mail Drop 4, 919/541-3374. For presentation at 40th Canadian Chemical Engineering Conference, Halifax, Nova Scotia, Canada, 7/15-21/90.

16. ABSTRACT The paper discusses pilot-plant tests with a 28 cu m/min (1000 cfm) electrostatic precipitator (ESP) to evaluate techniques that have a potential for enhancing the SO2 removal of the E-SOx process for retrofit application. The techniques investigated included mass-transfer additives, improved gas/liquid contact, product recycle, and recycle activation through a combination of hydrating, heating, and mixing. Marginal effects were obtained with the mass-transfer additives tested. Improving the gas-flow pattern and gas/liquid contact had a positive influence on SO2 removal and demonstrated the importance of flow control and spraying system design. Significant SO2 removal enhancement was obtained with recycle operation. When the recycle material was further activated, SO2 removal of 60-65% was achieved at a lime stoichiometry of 1.2.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Pollution Control	13B 21D
Flue Gases	Stationary Sources	21B
Coal	E-SOx Process	07A, 07D
Combustion		07B
Desulfurization		13I
Sulfur Dioxide		
Electrostatic Precipitators		
Calcium Oxides		

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL
INFORMATION SERVICE
SPRINGFIELD, VA 22161

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 23
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

PB90-262916

EPA/600/D-90/096

PILOT EVALUATION OF ENHANCED E-SO_x PROCESS

by

John C.S. Chang
Acurex Corporation
P.O. Box 13109
Research Triangle Park, NC 27709

and

Louis S. Hovis
U.S. Environmental Protection Agency
Air and Energy Engineering Research Laboratory
Research Triangle Park, NC 27711

For presentation at the 40th Canadian Chemical Engineering Conference
Halifax, Nova Scotia, Canada, July 15-21, 1990

ABSTRACT

Pilot-plant tests were conducted with a 28 m^3/min (1,000 cfm) electrostatic precipitator (ESP) to evaluate techniques that have a potential for enhancing the SO_2 removal of the E-SO_x process for retrofit application. The techniques investigated included mass-transfer additives, improved gas/liquid contact, product recycle, and recycle activation through a combination of hydrating, heating, and mixing. Marginal effects were obtained with the mass transfer additives tested. Improving the gas-flow pattern and gas/liquid contact had a positive influence on SO_2 removal and demonstrated the importance of flow control and spraying-system design. Significant SO_2 removal enhancement was obtained with recycle operation. When the recycle material was further activated, SO_2 removal of 60-65 percent was achieved at a lime stoichiometry of 1.2.

This paper has been reviewed in accordance with the U.S. Environmental Protection Agency's peer and administrative review policies and approved for presentation.

INTRODUCTION

The E-SO_x process is a flue-gas desulfurization (FGD) technology developed for low capital cost and for retrofit application to coal fired boilers (Hovis et al., 1988). The idea (Figure 1) is to modify an existing electrostatic precipitator (ESP) so that both particulate and SO_2 can be removed within the unit. The conceptual design showed that, with advanced ESP technologies like cold-pipe prechargers and large-diameter wires, it is possible to de-energize at least one section of an existing ESP and still meet the particulate emission limitations (Sparks et al., 1985). The E-SO_x concept centers on making use of the freed space (usually the first section) of a modified ESP for SO_2 removal. Typically, spray drying is adapted so that SO_2 is removed by an aqueous spray of an alkaline material (i.e., lime or sodium carbonate). A dry product containing a mixture of calcium sulfite salts, unused sorbent, and fly ash is formed in the first section and subsequently removed from the flue gas in the following sections of the modified ESP.

A proof-of-concept pilot-plant program sponsored by the U.S. Environmental Protection Agency's (EPA's) Air and Energy Engineering Research Laboratory (AEERL) has demonstrated the technical and economical feasibility of the E-SO_x concept (Hovis et al., 1989). More than 50 percent SO_2 removal efficiency with lime slurry injection was achieved at a stoichiometry of 1.4 and an approach to saturation temperature of 16.7 °C (30 °F). An economic evaluation based on the pilot-plant results showed that E-SO_x is a cost-effective process for retrofit application (Becker and DuBard, 1987).

Following proof-of-concept tests, a 5 MWe field demonstration program was conducted as a result of a cooperative effort by the EPA, the Ohio Coal Development Office (OCDO), and Babcock & Wilcox (B&W). The host site was Ohio Edison's R.E. Burger Station, located in Dilles Bottom, OH. A slipstream of flue gas from either boiler unit 7 or 8 was taken from the ductwork and redirected into a transportable ESP equipped with cold-pipe prechargers. Slaked lime was injected into the spray chamber ahead of the ESP for SO_2 removal. The field demonstration data confirmed EPA pilot-plant results, which showed that 50 percent or more SO_2 can be removed by the E-SO_x process at a reasonable lime stoichiometry (1.3-1.4).

To improve the E-SO_x process, EPA performed second-phase pilot-plant testing. The major objective was to evaluate techniques that may enhance SO_2 removal (or lime utilization). Because the lime utilization in E-SO_x has been lower than 40 percent and because the reagent cost has been a significant contributor to operating costs, it is desirable from both technical and economical perspectives to increase the utilization. Another objective of the pilot-plant tests was to optimize the ESP performance and to investigate factors that caused unrepresentative ESP behavior during the field testing period (Marchant et al., 1990).

This paper focuses on the SO_2 removal and lime utilization enhancement pilot-plant testing. Four techniques—mass-transfer additives, improved gas/liquid contact, product recycle, and activated recycle—have been investigated during the pilot-plant testing. Positive results were obtained when the last three techniques were evaluated. Owing to the similarity between the E-SO_x process concept and the SO_2 removal mechanism of spray drying and duct injection, the results from E-SO_x pilot testing may be useful for these FGD processes.

TEST FACILITY

As shown in Figure 2, the EPA E-SO_x pilot facility (Hovis, 1990) at the AEERL consists of an ESP capable of handling about 28 m^3/min (1,000 cfm) of simulated flue gas. The gas was made up by drawing outdoor air through the natural gas heater to raise the temperature to about 149 °C (300 °F). Pure SO_2 was injected into the heated air to simulate the burning of moderately high sulfur coal. Fly ash was then aspirated countercurrently into the simulated flue-gas stream before it entered the front end of the ESP. All the electrical components in the front end and the first section of the ESP were removed to create a spray chamber (Figure 1). A two-fluid nozzle designed to provide an oblong spray pattern was installed to make the emptied space a spray chamber. A slaked-lime slurry was pumped through the nozzle and atomized into fine droplets with a Sauter mean diameter of about 30 μm. The gas residence time in the spray chamber was estimated to be about 1.5-2 s. Inside the chamber, SO_2 was removed from the flue gas and absorbed by the lime slurry droplets. The droplets were dried by evaporating most of the water, forming a powder-like product with 10-20 percent moisture. Evaporation produces a flue-gas temperature drop, the magnitude of which depends on the volume of water sprayed. Normally, the

spray chamber outlet flue-gas temperature is controlled at a greater than 16.7 °C (30 °F) approach to saturation; that is, 16.7 °C (30 °F) above the dewpoint so that the solid product that enters the remainder of the ESP is sufficiently dry for efficient ESP operation. The electrical components of the remainder of the ESP are left intact so that it operates as a particle collector. Two cold-pipe prechangers were installed to aid in particulate collection: one between the first and the second sections, and the other between the third and the fourth sections. A slipstream of flue gas was drawn from the ESP outlet sample tap continuously for SO_2 analysis. A DuPont 400 ultraviolet SO_2 analyzer was used to monitor the dried and filtered sample gas.

The fly ash used for E-SO_x experiments was obtained from Detroit Edition Power Station, which burns Eastern high sulfur coal. Chemical analysis showed that the fly ash contained less than 3 percent calcium and did not react with SO_2 under typical E-SO_x conditions. The Mississippi Lime Company provided powdered quicklime with greater than 95 percent purity. A temperature-controlled mixing tank was used to slake the quicklime. After the lime was slaked, the lime slurry was filtered to remove the grit and then transported by a positive displacement (Mono) pump to the spray nozzle. The lime feed rate was measured every 30 min and controlled at desired stoichiometry, defined as:

$$\text{Lime stoichiometry} = \frac{\text{mole of Ca fed}}{\text{mole of } SO_2 \text{ injected}}$$

which is related to lime utilization by:

$$\text{Lime utilization} = \frac{SO_2 \text{ removal efficiency}}{\text{lime stoichiometry}}$$

RESULTS AND DISCUSSION

Four series of tests have been conducted in the pilot plant. Typical operating conditions are listed in Table 1.

Mass Transfer Additive Tests

Each test was conducted by spiking the lime slurry with a small amount of the additive to be evaluated. Sufficient time was allowed to ensure good mixing and the complete dissolution of the additive

in the sorbent preparation tank. SO_2 removal before and after the additive spiking was continuously monitored. Since the operating conditions remained unchanged, the ESP outlet SO_2 concentration should reflect the effectiveness of the additive on SO_2 removal.

The first additive tested was calcium chloride, which was supposed to act as a deliquescent agent to enhance the water retention capability of the E-SO_x product and to prolong the slurry droplet drying time. In general, wet sorbent is more reactive toward SO_2 than dry sorbent. However, as shown in Table 2, no effect on SO_2 removal was detected at calcium chloride concentrations up to 2 percent.

Three more groups of additives were evaluated. Adipic acid, monoethanol amine, aminoacetic acid, ammonium phosphate, and sodium phosphate were tested because they could potentially function as buffer additives. Mass transfer theory (Chang and Rochelle, 1982) showed that, if the SO_2 removal were predominantly liquid-phase diffusion controlled, the additives that buffer between the pH of the gas/liquid interface (typically 3-4) and the pH of the calcium hydroxide surface (typically 11-12) would enhance the diffusion of SO_2 species and increase SO_2 removal. Another group of additives, sugar and two chemicals provided by NALCO Chemical Company, were tested because of their potential to increase the solubility of lime. In addition, lignosulfonate was evaluated as a crystal modifier, because literature data showed that lignosulfonate, when used as an additive, could reduce the potential of agglomeration and increase the gas/solid contact (Kirchgessner and Jozewicz, 1989).

Table 2 shows that, among all the additives tested, only ammonium phosphate and sodium phosphate exhibited marginally positive effects on SO_2 removal. Less than 3 percent increase in SO_2 removal was obtained when phosphate salt concentration was about 4,000 ppm. The odor of ammonia was detected around the slurry tank during the ammonium phosphate testing.

Improved Gas/Liquid Contact

A baffle was installed upstream of the spray nozzle in an effort to improve the gas/liquid contact. The baffle (Figure 3) has an oval opening in the center. The area of the opening is about 25 percent of the total gas passage. Therefore, the flue gas would go through converging/diverging actions when it passed the baffle. The spray nozzle was situated near the center of the opening. The intention was to direct more flue gas toward the center of the spray, where most droplets were located. The gas/liquid

contact could also be improved by the turbulence created by the converging/diverging actions of the flue gas. Figure 4 shows a comparison of SO_2 removal efficiency of the E-SO_x pilot-plant with and without the baffle. A 6-8 percent increase in SO_2 removal was obtained by installing the baffle. The lime stoichiometry was controlled at 1.1 for the data shown in Figure 4. Further testing indicated that the increase in SO_2 removal diminished with the increase of lime stoichiometry. When the lime stoichiometry was raised to 1.4, the SO_2 removal enhancement decreased to about 3 percent.

Recycle Tests

To assess the potential benefits of product recycle of the E-SO_x process and to provide guidance for pilot testing, a test plan was developed from a computerized mathematical model that can predict overall lime utilization, SO_2 removal efficiency, and the ESP solids loading with recycle operation (Chang, 1989). The model was established based on the following assumptions:

- No difference exists between new and old (recycled) lime in terms of reactivity
- 40 percent of the lime is reacted each time it passes through the E-SO_x pilot plant
- The recycle product is predominantly a mixture of fly ash, $CaSO_3 \cdot H_2O$, and $Ca(OH)_2$
- Fly ash, $CaSO_3 \cdot H_2O$, and $Ca(OH)_2$ exist in discrete solid phases, and there is no interference with one another (i.e., no blinding and recrystallization)
- All nozzles and pumps can handle 30 percent total solids slurry during recycle

Based on the model predictions, performance curves were generated. Figure 5 shows the effect of recycle operation on SO_2 removal efficiency at a lime stoichiometry of 1.0 for typical E-SO_x conditions listed in Table 1. The SO_2 removal efficiency increases (from 40 percent without recycle) with increasing recycle ratio and reaches about 57 percent at the maximum recycle ratio. The recycle ratio is defined as:

$$\text{Recycle ratio} = \frac{\text{kg of dry recycled solids}}{\text{kg of fresh } Ca(OH)_2 \text{ fed}}$$

The maximum recycle ratio, which is calculated based on the assumption that the spray nozzle can handle up to 30 percent total solids slurry, is one of the boundary conditions that define the operating window of the E-SO_x recycle process. For practical application, the fresh lime stoichiometry of the E-SO_x

process usually ranges from 0.9 to 1.5; correspondingly, the model predicts that the maximum recycle ratio of interest should be less than 3 and most likely between 1.5 and 2.5.

Figure 6 presents the comparison of SO_2 removal efficiency predicted by the model for E-SO_x with and without recycle and shows that the benefit of the recycle operation can be realized through either increase of SO_2 removal or decrease of lime stoichiometry or both. If E-SO_x is operated at a fixed lime stoichiometry (e.g., 1.3), Path a of Figure 6 shows that the SO_2 removal efficiency increases from 52 percent (without recycle) to 70 percent at maximum recycle. On the other hand, if SO_2 removal is maintained at 52 percent, Path b of Figure 6 shows that the fresh lime stoichiometry decreases from 1.3 (without recycle) to less than 0.9 at maximum recycle. As a result, lime consumption can be reduced significantly. Generally, 25-35 percent reduction in lime consumption is predicted by the model for the most probable E-SO_x operating range.

Pilot-plant tests were conducted to verify the model predictions. Because of ESP solids disposal limitations, the recycle tests were performed on a batch basis. Usually a minimum of four runs were made for each set of operating conditions. A baseline (once through) test was carried out to generate initial recycle solids. Three consecutive runs were subsequently made, and each run used the product obtained from the two previous tests as the recycle material. Figure 7 shows the pilot-plant data from a series of tests conducted at 1.2 fresh lime stoichiometry and 1.0 recycle ratio. Forty-eight percent SO_2 removal was obtained from the baseline test. The four recycle runs showed that the SO_2 removal efficiency varied in a narrow range of 52 to 57 percent. The average SO_2 removal from the four recycle tests is about 55 percent, which is 7 percent higher than the baseline. More encouraging is the upward trend of SO_2 removal for the last three runs indicating that long term, steady state SO_2 removal of continuous recycle should approach the high end of the data shown in Figure 7.

More pilot-plant tests were performed at the 1.2 lime stoichiometry but at different recycle ratios. Figure 8 shows the comparison of pilot-plant data with model predictions. Good agreement between the experimental data and the performance curve was obtained at a recycle ratio below 1.0. At a high recycle ratio, the SO_2 removal predicted by the model is usually 3-5 percent higher than the pilot-plant results. As the recycle ratio increased, the solids content of the slurry also increased. It is suspected that the

thick slurry caused some interference among the solid particles, through actions such as blinding and agglomeration. As a result, the overall lime utilization decreased, and the model, with the assumption that there is no interference among the solids, tended to predict the SO_2 removal efficiency slightly higher than the data indicated.

No significant operational problems were encountered during the recycle test period. The slurry with recycle material was actually easier to handle than slaked lime. The pilot-plant Mono pump used to be able to handle a slaked-lime slurry up to about 21 percent solids. When recycle material was added, the pump had no difficulty pumping slurry with solids up to 32 percent. Apparently, the change of the slurry composition and the abrasive property of the fly ash considerably decreased the slurry viscosity and made the pump work more efficiently. The drying property of the slurry also changed with the addition of recycle material. It was found that the approach to saturation temperature could be decreased to about 13 °C (23 °F) for recycle tests, which is lower than the 16.7 °C (30 °F) of once-through runs. The product of recycle tests was damp, containing moisture up to 25 percent, yet not sticky. No plugging or scaling problems occurred. The presence of fly ash may have made the slurry more abrasive compared to slaked lime. A abrasion-resistant alloy or abrasion-free design has to be used for spray nozzles to reduce maintenance.

Activated Recycle

A previous study (Jozewicz and Rochelle, 1986) has shown that the reactivity of lime toward SO_2 can be enhanced by mixing lime with materials containing silica in water at an elevated temperature for a minimum of 8 h. Calcium aluminum silicate hydrates are the most likely products of this reaction. The hydrates produced have a very large surface area (100-300 m^2/g has been reported) and exhibit high affinity toward water. The detailed reaction mechanisms between SO_2 and the hydrates are still under investigation. The large surface area and the associated high moisture-retaining ability may contribute to the high reactivity of the hydrates toward SO_2. This concept has been further developed into a damp solids duct injection FGD process (ADVACATE process) by using fly ash as the source of silica containing material (Chang and Sedman, 1989). The fly-ash-to-lime ratio was usually 3 or higher, and the reaction temperature for fly ash and lime was 90 °C or higher. When this concept was applied to spray

drying, operating problems were encountered. Significant wet deposits, apparently related to drying difficulties, built up on the spray dryer wall until the approach to saturation was raised above 50 °C (90 °F), at which no SO_2 removal occurred (Chang and Jorgensen, 1989).

To adapt this concept to the E-SO_x process for activated recycle tests, it was decided to hydrate the recycle material at an elevated temperature to facilitate the reaction between fly ash and lime. Slurry containing 20-30 percent recycled solids was heated to 90 °C in a stirred tank. The "hydration time" varied between 8 and 16 h. After the hydration was finished, the slurry was mixed with slaked lime and injected into the ESP spraying chamber to remove SO_2. Figure 9 shows the SO_2 removal efficiency obtained with the activated recycle. The recycle material is apparently activated by the hydration process, especially when the hydration time is 10 h or longer. SO_2 removal between 60 and 65 percent was achieved at 1.2 fresh lime stoichiometry and 1.0 recycle ratio, which is considerably higher than the baseline (48 percent) and conventional recycle (55 percent) SO_2 removal. Contrary to previous spray-drying results, no drying problems or wet deposits were encountered during the E-SO_x activated recycle tests. Comparing the operating conditions between the two tests, it was found that the fly-ash-to-lime ratio was quite different. Previous spray-drying tests used a slurry with a fly-ash-to-lime ratio of 5.0. Current E-SO_x tests used the recycle solids with a fly-ash-to-lime ratio of less than 1.0. The low ash-to-lime ratio might have limited the extent of reaction and resulted in the formation of some underdeveloped calcium-aluminum-silicate hydrates. It is suspected that those semi-developed hydrates may still be reactive to SO_2 and yet may not be as difficult to dry as those fully developed hydrates obtained at high ash-to-lime ratios.

Future Plans

Among the four techniques evaluated, activated recycle is the most promising one that can potentially increase the lime utilization to above 50 percent. As discussed earlier, the benefit of recycle operation can be realized through the increase of SO_2 removal, decrease of lime stoichiometry, or a combination of both. If the reduction of lime consumption is the main purpose of the recycle operation, the model developed in current work predicts that approximately 15 percent reduction in waste product can also be achieved owing to the lower lime consumption. One of the main concerns of the recycle

operation is the effect on dust loading and ESP performance. For the E-SO_x recycle operation, the increase in flue-gas dust loading is expected to be in the range of 150-250 percent when compared with the baseline (no recycle). Pilot-plant tests are planned to evaluate the effect of dust-loading increase on particulate emissions, because ESP performance (particulate removal efficiency) depends not only on dust loading, but also on parameters such as particle size, shape, and resistivity.

To make the activated recycle more cost effective, the hydration time and temperature should be substantially reduced. It is also desirable to minimize the recycle ratio. These proposals will involve systematic pilot-plant testing and some fundamental research on the reaction mechanism and kinetics between fly ash and lime, especially at a low ash-to-lime ratios. One technique under consideration is grinding the recycle solids before hydration, which should reduce the particle size, increase the solid surface area, expose more reactive solids, and enhance reaction rate between fly ash and lime. Efforts will also be made to combine the slaking and hydration operation to simplify the whole E-SO_x process and to utilize the heat generated from lime slaking for hydration.

References

Becker, D.F. and J.L. DuBard, "Conceptual Designs and Cost Estimates for E-SO_x Retrofits to Coal-Fired Utility Power Plants," EPA-600/7-87-028 (NTIS PB 88-143995). U.S. Environmental Protection Agency, Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, December 1987.

Chang, J.C.S. and G.T. Rochelle, "Effect of Organic Acid Additives on SO_2 Absorption into $CaO/CaCO_3$ Slurries," AIChE J., 28, 2, 261, March 1982.

Chang, J.C.S., "Test Plan for In-House E-SO_x Recycle Evaluation," memo to Lou Hovis, EPA/AEERL, January 1989.

Chang, J.C.S. and C.B. Sedman, "Scale-Up Testing of the ADVACATE Damp Solids Injection Process," Proc. First Combined FGD and Dry SO_2 Control Symposium, Vol. 3, EPA-600/9-89-036c (NTIS PB89-172175), March 1989, 8-122.

Chang, J.C.S. and C. Jorgensen, "Evaluation of FGD Dry Injection Sorbents and Additives, Vol. 2. Pilot Plant Evaluation of High Reactivity Sorbents," EPA-600/7-89-006b (NTIS PB89-214134), May 1989.

Hovis, L.S., R.E. Valentine, J.L. DuBard, and J.C.S. Chang, "E-SO_x System for Combined Particulate and SO_2 Control," Proc. Seventh Symposium on the Transfer and Utilization of Particulate Control Technology, Vol. 2, EPA-600/9-89-046b (NTIS PB89-194047), May 1989, 19-1.

Hovis, L.S., R.E. Valentine, B.J. Jankura, P. Chu, and J.C.S. Chang, "E-SO_x Pilot Evaluation," Proc. First Combined FGD and Dry SO_2 Control Symposium, Vol. 3, EPA-600/9-89-036c (NTIS PB89-172175), March 1989, 8-177.

Hovis, L.S., "An Evaluation of the E-SO_x Process on the EPA Pilot Electrostatic Precipitator," EPA-600/7-90-011, May 1990.

Jozewicz, W. and G.T. Rochelle, "Fly ash Recycle in Dry Scrubbing," Environmental Progress, 5, 4, November 1986.

Kirchgessner, D.A. and W. Jozewicz, "Enhancement of Reactivity in Surfactant-Modified Sorbents for Sulfur Dioxide Control," I&EC Research, 28, 4, 413, 1989.

Marchant, G.H. Jr., J.P. Gooch, M.G. Faulkner, and L.S. Hovis, "Effects of E-SO_x Technology on ESP Performance," Presented at the Eighth Symposium on the Transfer and Utilization of Particulate Control Technology, San Diego, CA, March 1990.

Sparks, L.E., N. Plaks, G.H. Ramsey, and R.E. Valentine, "Investigation of Combined Particulate and SO_2 Using E-SO_x," Proc. Ninth Symposium on Flue Gas Desulfurization, Vol. 2, EPA-600/9-85-033b (NTIS PB86-138658), December 1985.

TABLE 1. TYPICAL OPERATING CONDITIONS OF E-SO_X PILOT TESTING

Flue gas	
Inlet temperature	149 °C (300 °F)
SO_2 concentration	2,000 ppm
Fly ash concentration	1.9 g/L (1 gr/ft^3)
Sorbent	Mississippi lime
Approach to saturation	13.9-22.2 °C (25-40 °F)
Lime stoichiometry	1.1-1.4
ESP	
Plate height	1.2 m (4 ft)
Plate length	1.5 m (5 ft)
Plate spacing	22.9 cm (9 in)
Gas flow passage	1
Number of sections	3
Power supply	100 kV; 10 mA
Corona wire diameter	0.32 cm (0.125 in)

TABLE 2. RESULTS OF MASS TRANSFER ADDITIVE TESTS

Additives	Concentration Range	Effects on SO_2 Removal
Deliquescents		
Calcium Chloride	0.5 ~ 2 percent	No effect
Buffer Additives		
Adipic Acid	500 ~ 3,000 ppm	No effect
MEA (Monoethanol Amine)	500 ~ 3,000 ppm	No effect
Glycine (Aminoacetic Acid)	500 ~ 5,000 ppm	No effect
Ammonium Phosphate	500 ~ 4,000 ppm	Marginally positive (<3 percent improvement)
Sodium Phosphate	500 ~ 4,000 ppm	Marginally positive (<3 percent improvement)
Solubility Enhancement		
Sugar	1 ~ 2 percent	No effect
NALCO-109	5 ~ 100 ppm	No effect
NALCO-126	5 ~ 100 ppm	No effect
Crystal Modifier		
Lignosulfonate	1 ~ 2 percent	Slightly negative

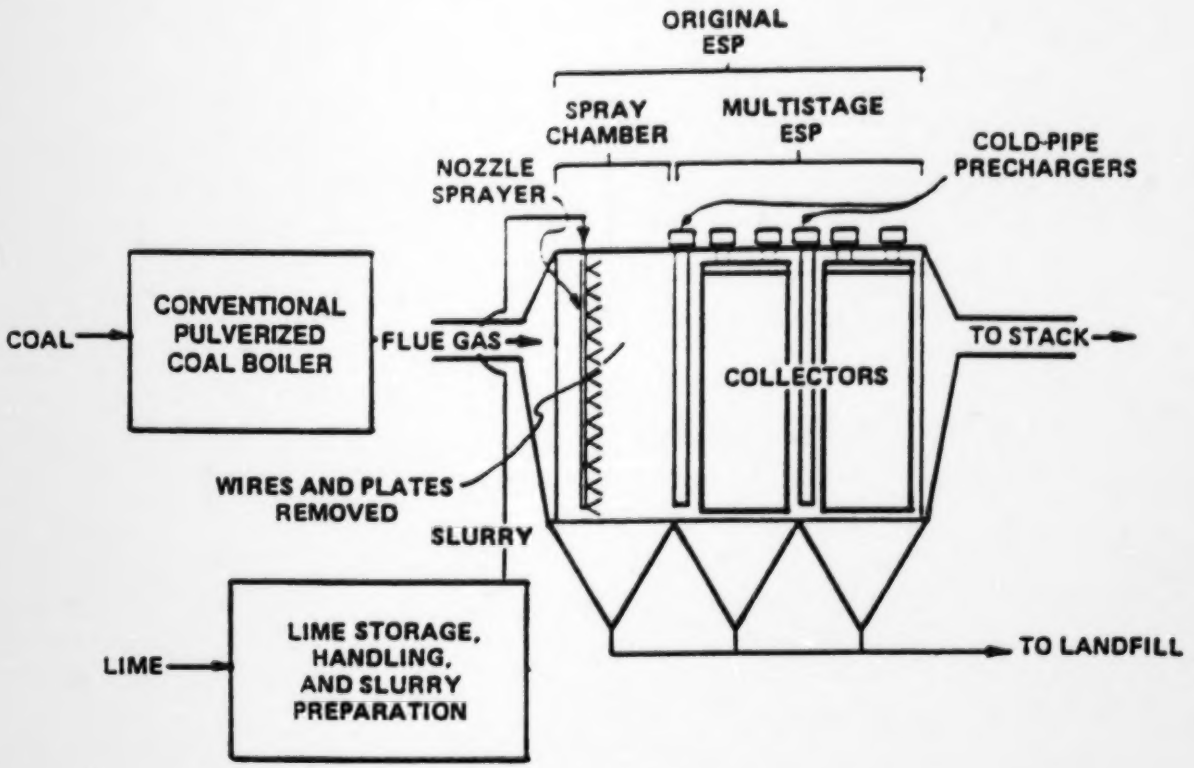
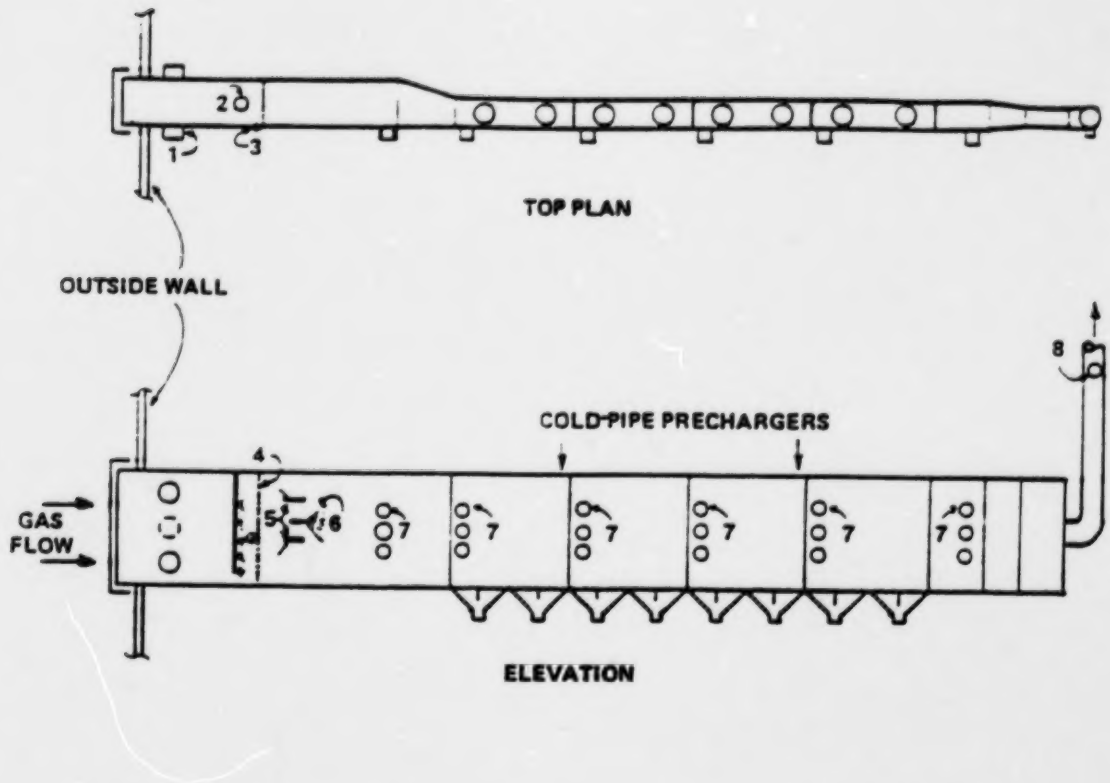


Figure 1. Schematic of E-SO_x process



1. NATURAL GAS BURNERS
2. SO_2 INJECTORS
3. BURNER TEMP. CONT. T. C. S
4. PERFORATED PLATE
5. ASH INJECTORS (AGAINST GAS FLOW)
6. ATOMIZER TIP
7. SAMPLING PORTS
8. OUTLET SAMPLE TAP

Figure 2. EPA E-SO_x pilot facility, 1,000 acfm (28 m^3/min) ESP with spray zone

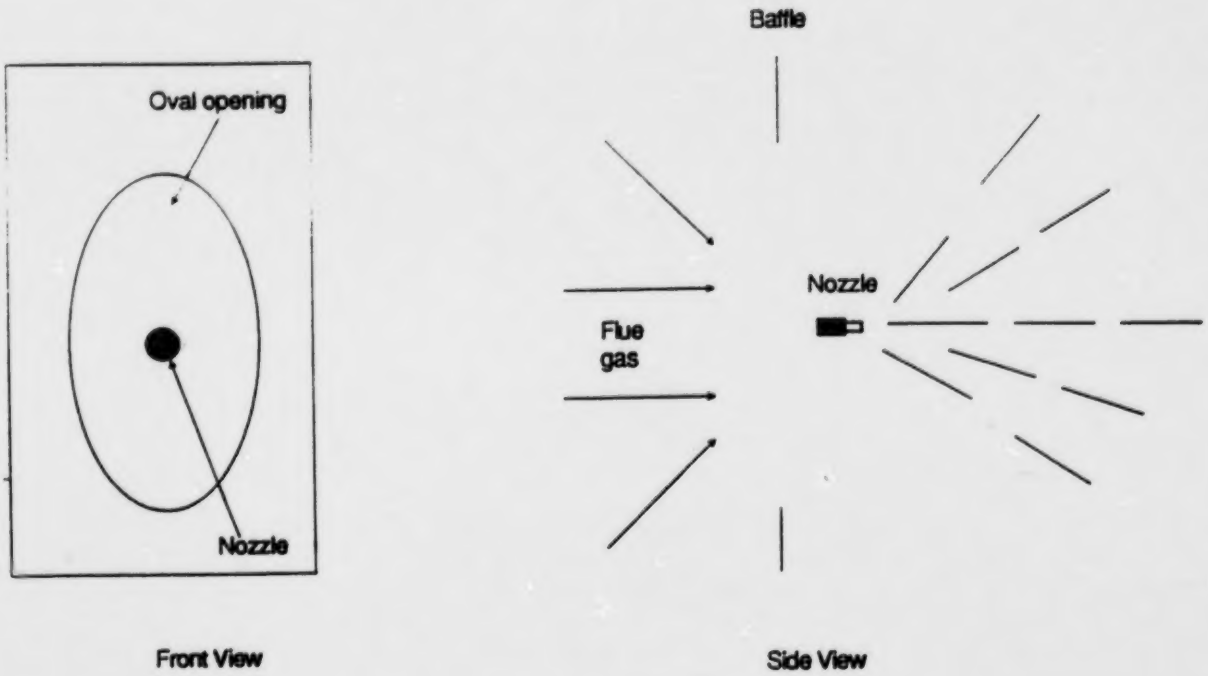


Figure 3. Baffle installed in the E-SO_x pilot plant (not to scale).

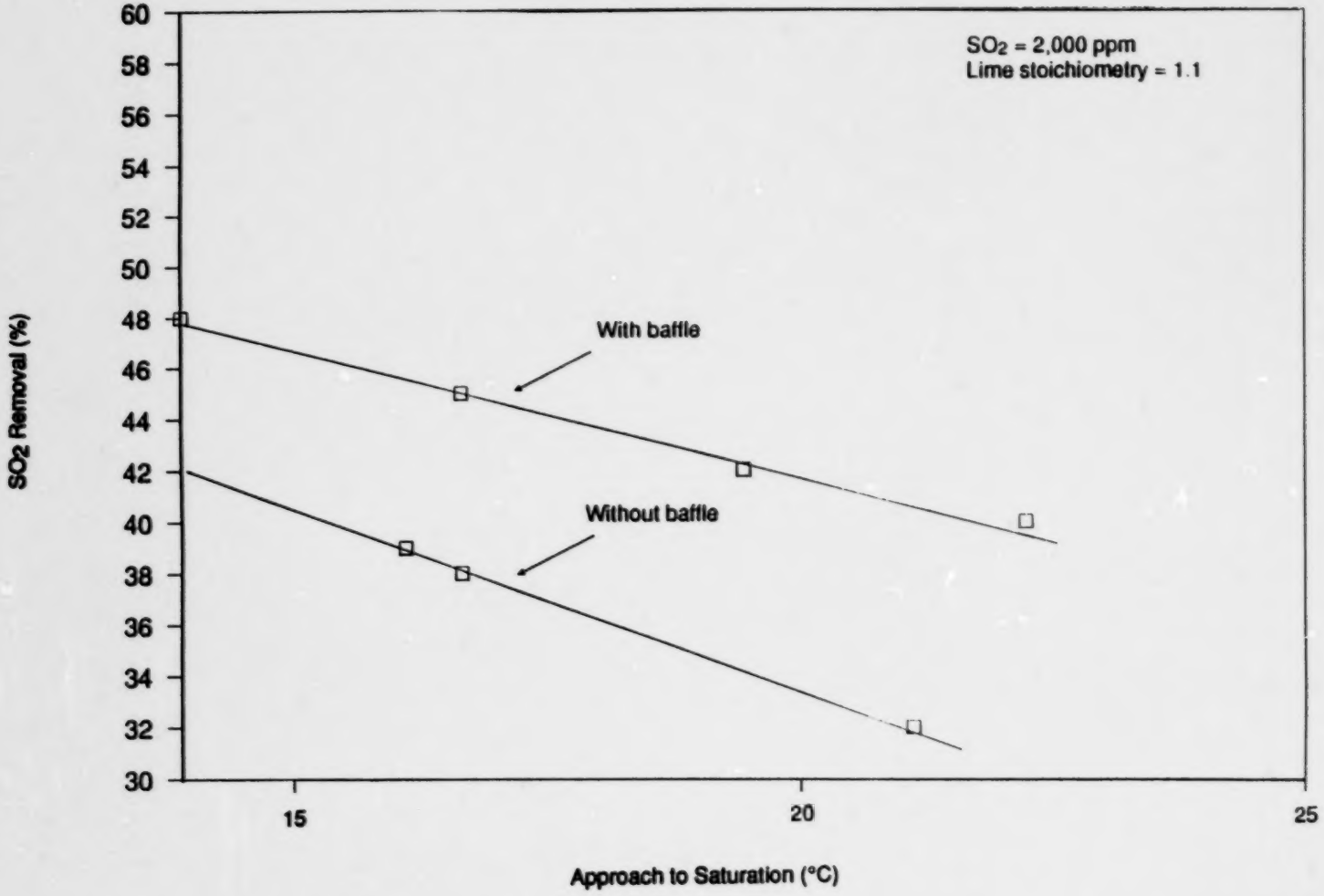


Figure 4. Effect of baffling on SO_2 removal.

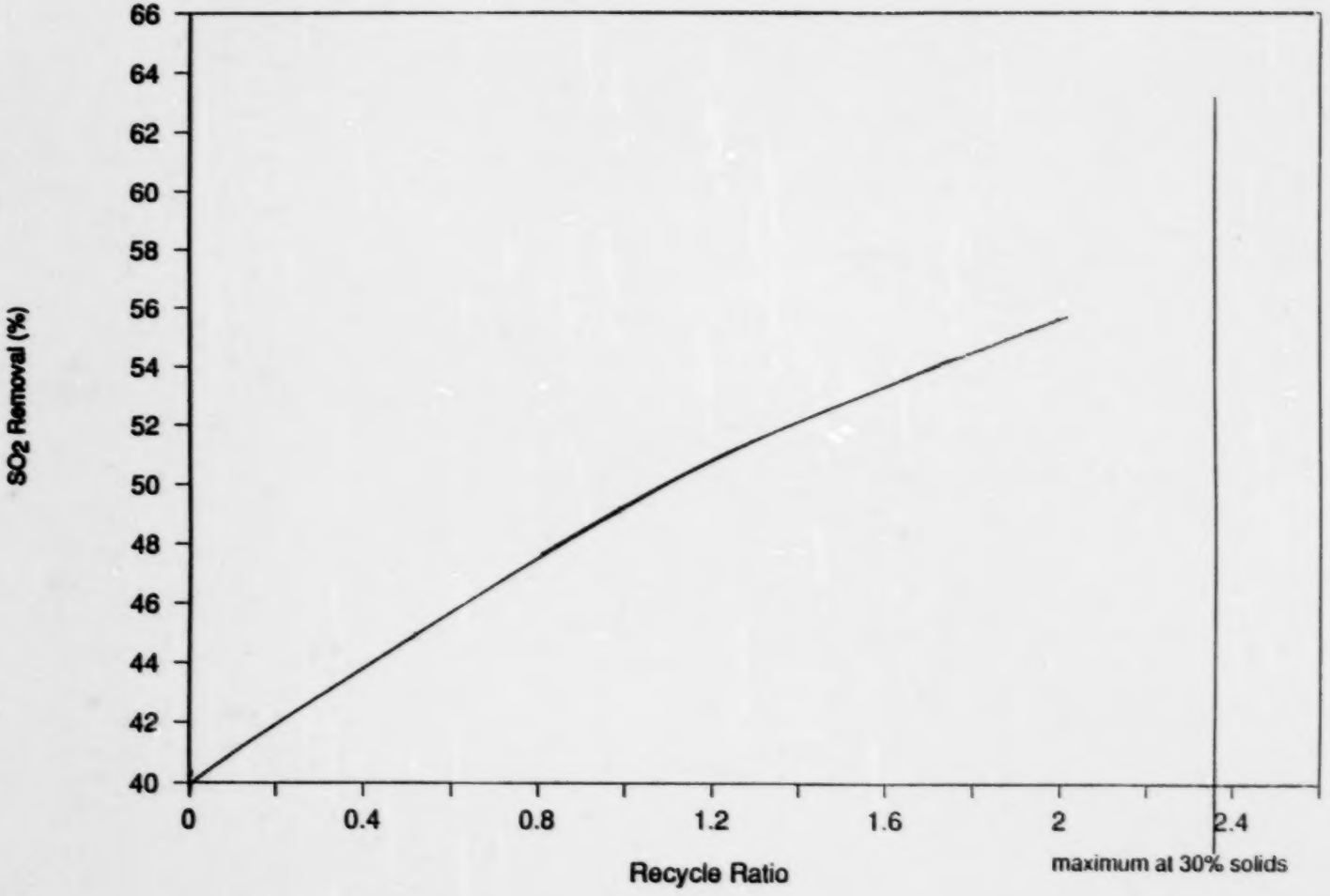


Figure 5. Effect of recycle ratio on SO_2 removal at fresh lime stoichiometry of 1.0.

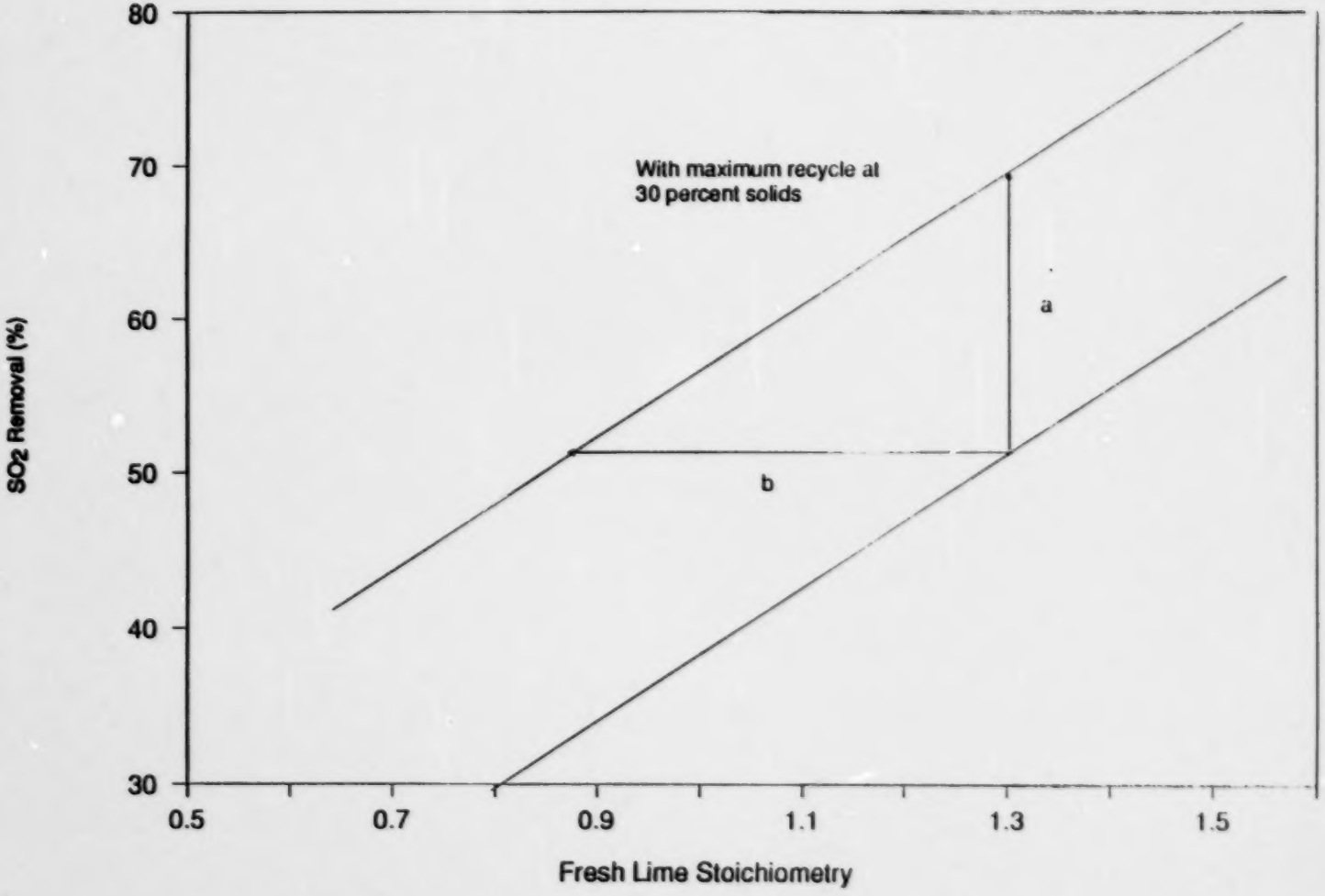


Figure 6. Comparison of SO_2 removal efficiency for E-SO_x with and without recycle.

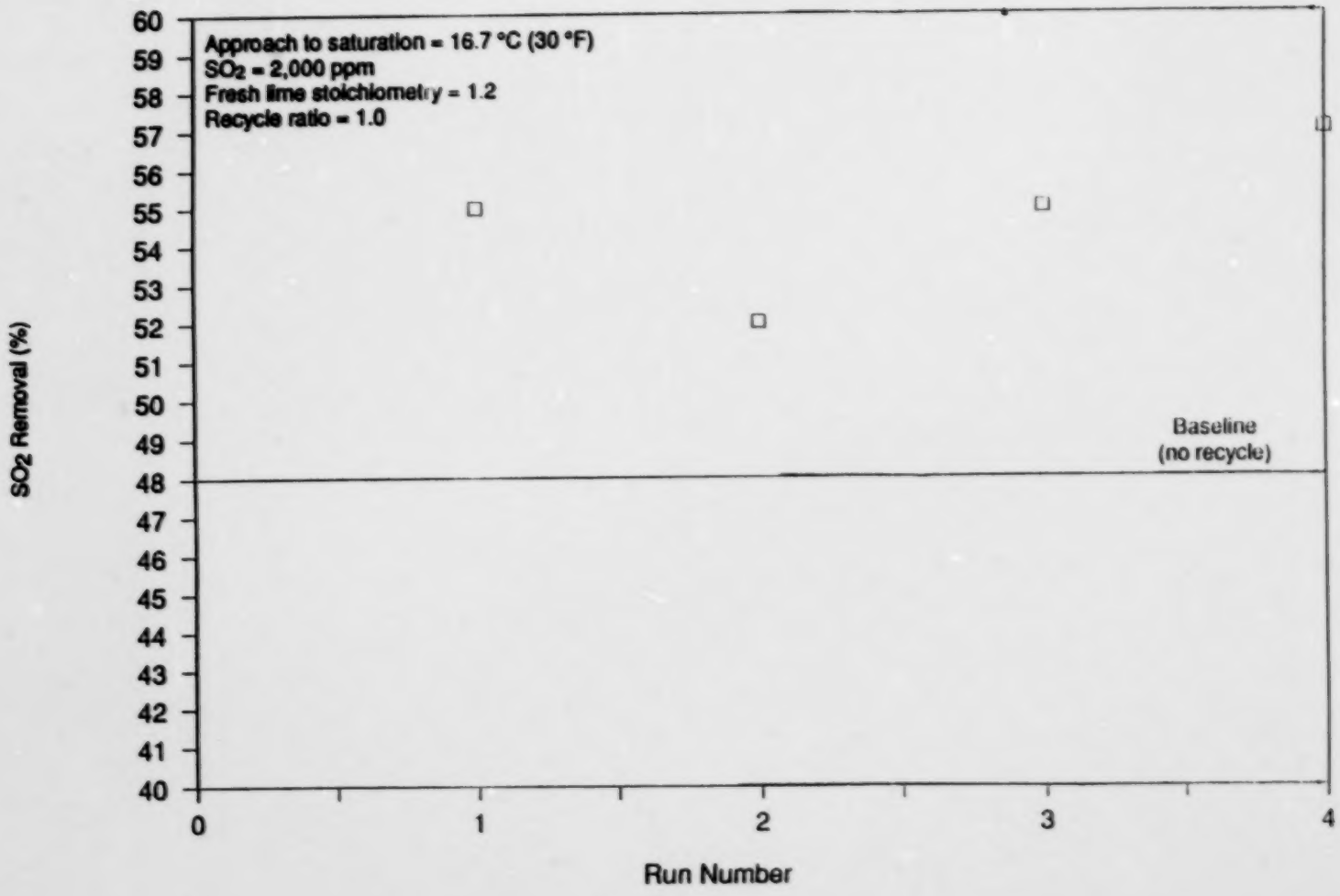


Figure 7. Results of pilot-plant recycle tests.

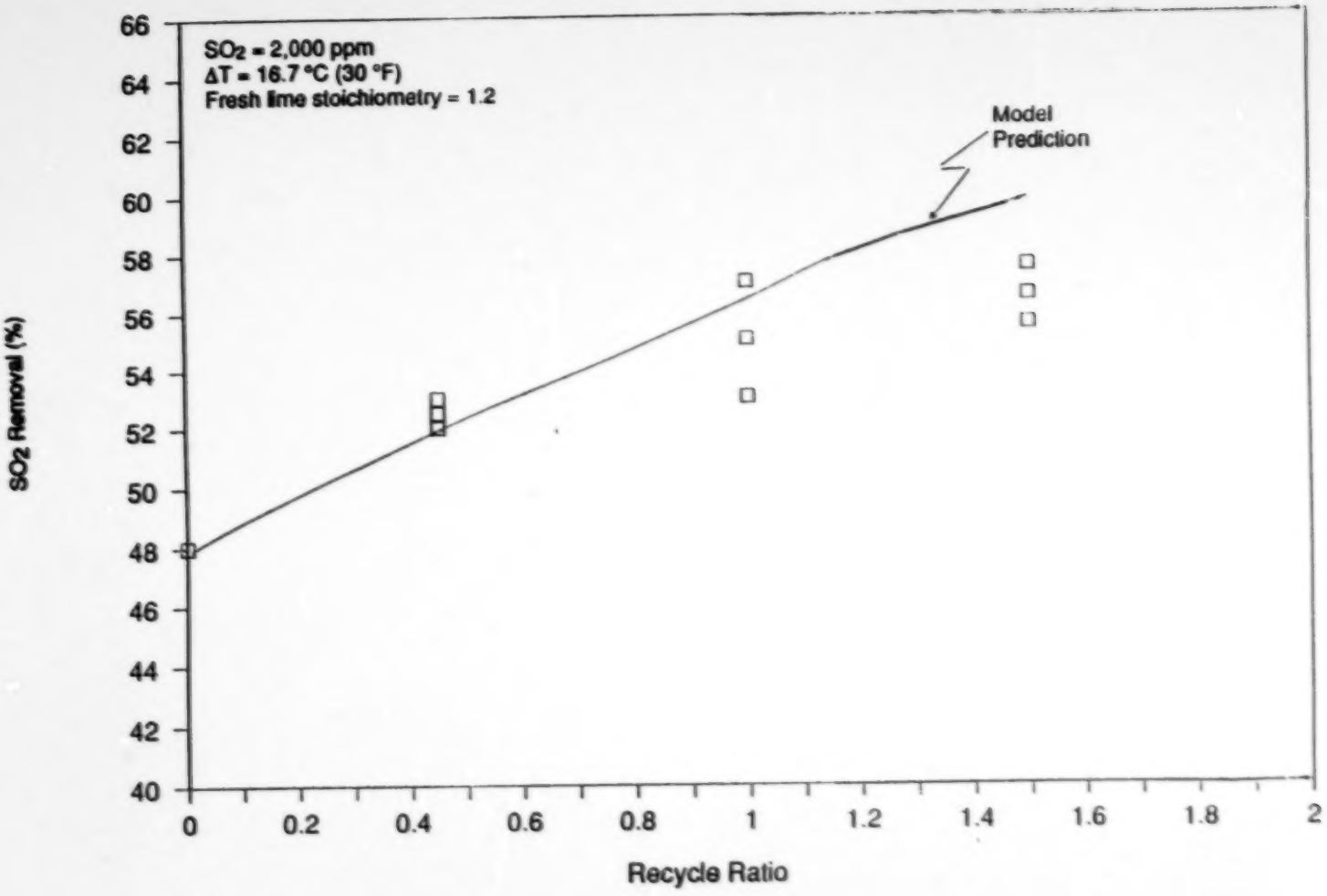


Figure 8. Comparison of pilot-plant data with model predictions.

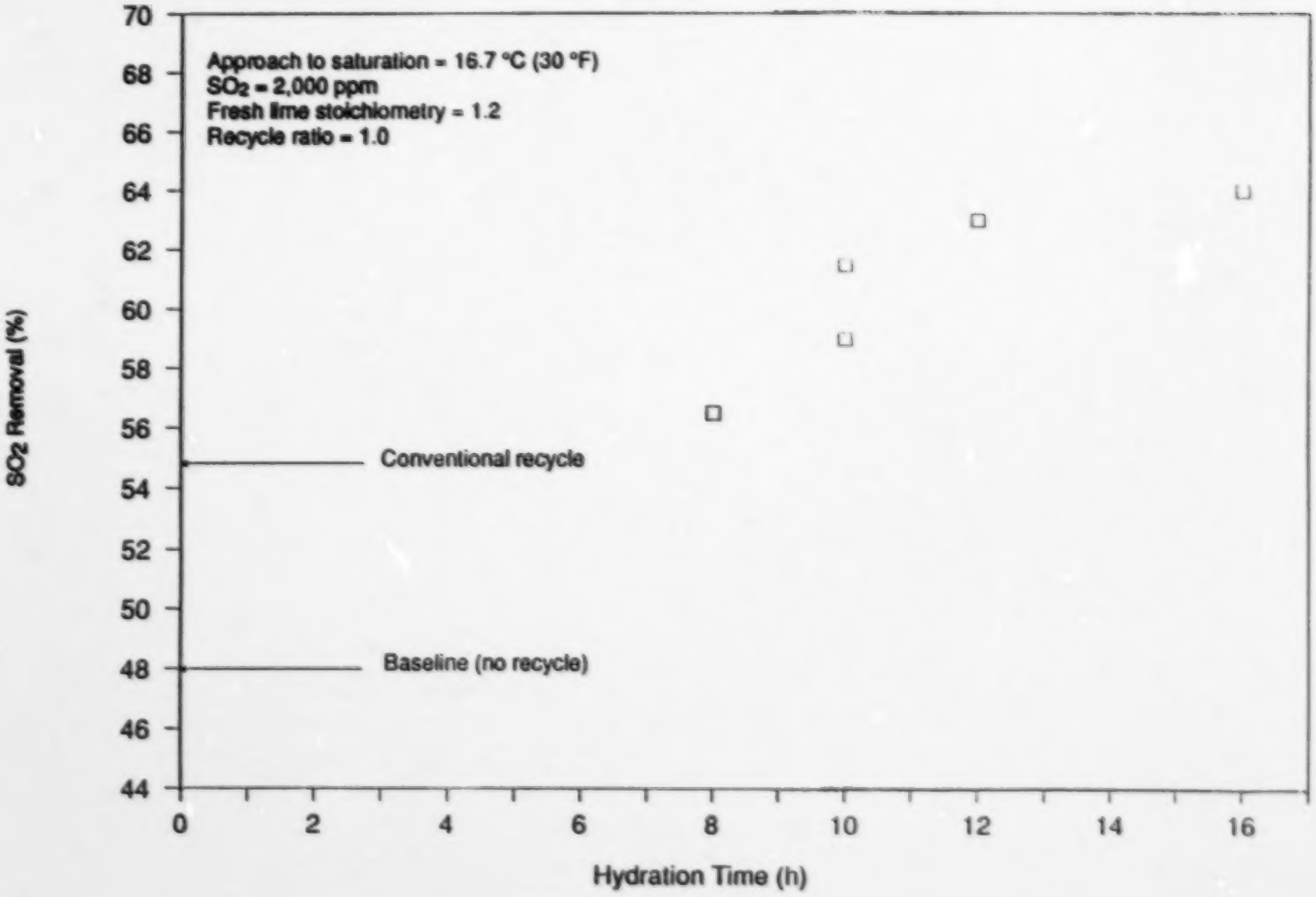


Figure 9. Results of pilot-plant activated recycle tests.